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Real Time Virtual Human Hand Using Leap Motion Controller

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***Abstract*—the research of robotics needs a good and accurate control. The proposed concept is touch less and non-verbal communication with the use of leap motion controller. The concept has two major parts: first part is "device perceive hand finger moments and send signal", second part is robotic hand interfaced with PIC microcontroller which receives signal and controls robotic hand. The paper aims to link virtual environment with real time environment. The virtual environment is consisting of leap motion controller and laptop, real time environment is consisting of microcontroller and robotic arm. In real time environment parodist is converts into virtual environment.**

***Keywords*—gesture, leap motion controller, and robotic arm**

I. Introduction

THE development of advanced gesture recognition sensors habitually used in robotic hand control. In wide and variety of areas robotics is substitutes for human work [1]. Leap motion controller creates virtual screen to visualize hand gesture information and the same information send to robotic hand through wireless device support [2]. For hand gesture recognition many sensors used like MEMS accelerometer, EMG, Gyroscope, flex sensor, pressure sensor [3] [17].

LMC used to achieve hand of human intension by interaction of Robotics. Leap motion controlled good to recognize the intension of human by gesture of human hand and fingers [4]. LMC supports to complete virtual task like virtual game, virtual selection, virtual control, and all virtual environments based applications [5].

Gesture recognition of LMC used to control vehicles, robotics, and drones with the decision of human. At some kind of hazardous situation human brain takes the good decision [7]. LMC creates virtual reality environment for virtual game, virtual pen, virtual instruments performs simulated operations [8]. LMC can be used like mouse, and joystick. By using LMC gesture recognition, user can interact with virtual reality (VR) environment. This method is a touch less interaction to communicate robotics [11] [12].

II. Related work

Leap motion controller finds the touch less human computer interface. LMC creates virtual environment in computer for various task handling. Interaction of objects by using LMC is a unique way of hand gesture recognition.

It supports various compilers and IDEs such as Visual Studio, Xcode3.0+, Mono version 2.10, Unity Pro and personal version 5.0, java versions 6and 7, python version 2.7.3, and Unreal Engine 4.9. All header files and library files, DLL files provided by leap SDK required to develop leap motion controller enabled application. Hand gesture recognition is done by LMC on both hands dynamicaly and simultaniously. It can be used in virtual game, virtual air brush, virtual desktop application, virtual mouse and keyboard.LMC consist of three IR LEDs and two IR cameras which visualize the skeletal point in computer similar to human finger moments. It uses specialized software to visualize skeletal point of finger. Many devices are used for motion capture but leap motion controller has built-in IR sensor to detect human hand and two cameras to capture the gesture of human hand which processed by software. Distance between the above the LMC and human hand should be approximately 20 centimeters. The distance between around the leap motion controller and human hand should be approximately 45 centimete [6] [18].

Fig. 1. Leap Motion Controller interface with virtual environment

The Fig. 1 shows the interface of LMC with computer using USB communication port and its virtual simulation environment as output.

A. Software for leap motion controller

Special software program required to use leap motion controller for tracking human hand. The leap motion controller SDK (software development kit) is written in C++, Java, Java Script, Objective C, C#, Python. It supports Windows, Linux and Macintosh operating system. The advantage of this is to make any software program to track human hand. Since the tracking of human hand can make own software.

B. Schematic of LMC

Fig. 2 shows schematic diagram of leap motion controller. Gesture recognition using leap motion controller provide virtual and robotic hand grip. Each IR camera is placed between infra-red light emitting diodes (IR LEDs) [10].

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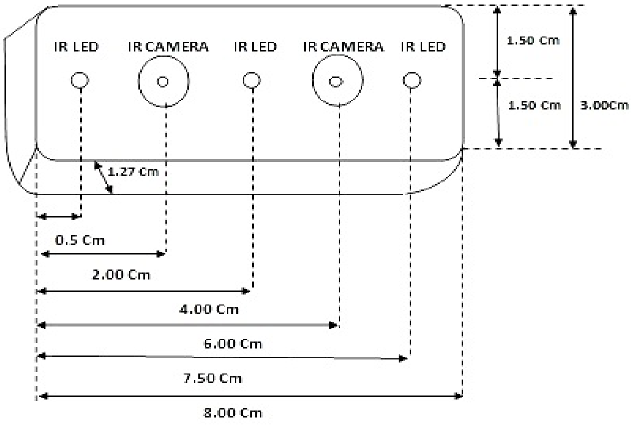

Fig. 2. Schematic of LMC

Fig. 2 shows the camera and IR LEDs are placed in unit of centimeter (cm). Form the left side of schematic first IR led is placed at a distance of 0.5cms, first Camera is placed at a distance of 2cm, second IR led is placed at a distance of 4cm, second camera is placed at a distance of 6cm, and third IR led is placed at a distance of 7.50cm. Total length, width, and height of leap motion controller are 8cm, 3cm and 1.27cm respectively. The wave lengths of IR LEDs are 850 nanometers.

C. Hand Skeletal

Fig. 3 shows the skeletal view of hand fingers. The distal phalanges, intermediate phalanges, proximal phalanges, metacarpals and carpals forms finger of human hand.

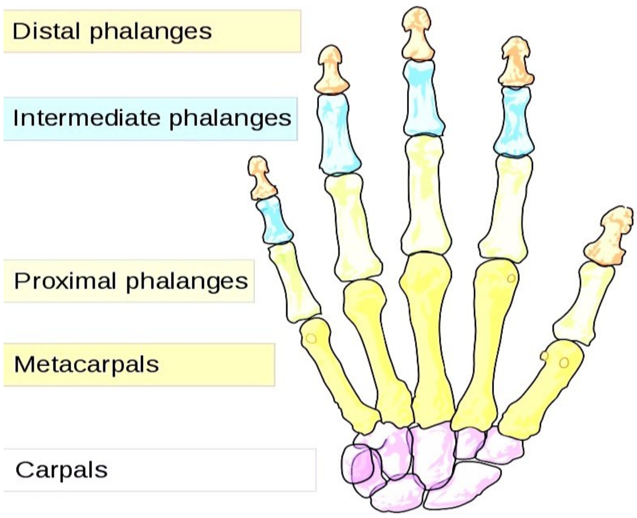

Fig. 3. Skeletal View of Hand fingers

Fig. 3 Leap Motion Controller takes standard skeletal model for tracking human hand. Two rows of four carpal bones is 8 bones forms wrist of the hand. The area between carpals and distal phalanges called hand. The metacarpals is 5 bones, phalanges is 14 bones, totally 27 distinct bones forms human hand.

III. PROPOSED WORK

The main motivation of this paper to is convert virtual hand into real time robotic hand. LMC generates 3D skeleton image while the information of that virtual image is sent to robotic hand. On transferring the hand signal it has subjected to image processing where the image features are extracted by ANN. The following three steps operate Real-Virtual-Robotic hand [9].

A. Real hand - camera of LMC captures the real hand and finger gesture fed into the laptop/PC.
B. Virtual hand - laptop/ PC visualize 3D image (virtual hand) and its related information send via wireless.
C. Robotic hand – 3D image Information received by robotic hand and it behave like real and virtual hand.

The proposed design is to convert the HCI (human computer interface) into HCRI (human computer robotic interface). The hand gesture image is captured and processed in ANN. The images are separated into the training and testing phase. In the training phase, the features vectors are evaluated through a multilayer neural network. Based on the feature vector, the performance of the ANN is evaluated using a new set of input data. ANN supports the proposed model to efficiently identify the hand signals.

A. Convert Human Hand Gesture Data into Virtual hand

Gesture of human hand is an input of this leap motion controller. IR sensor built in leap motion controller detects human hand motion and the two cameras built in leap motion controller capture the gesture of hand detected by IR sensors.

Hand gesture of LMC fed to the computer via USB communication port [13]. SDK present on the computer to manipulate the data of hand gesture for virtual simulation by visual C++ language and simulate the hand gesture in virtual environment. This virtual hand information from the computer is transfer to robot hand via ZigBee wireless device [7].

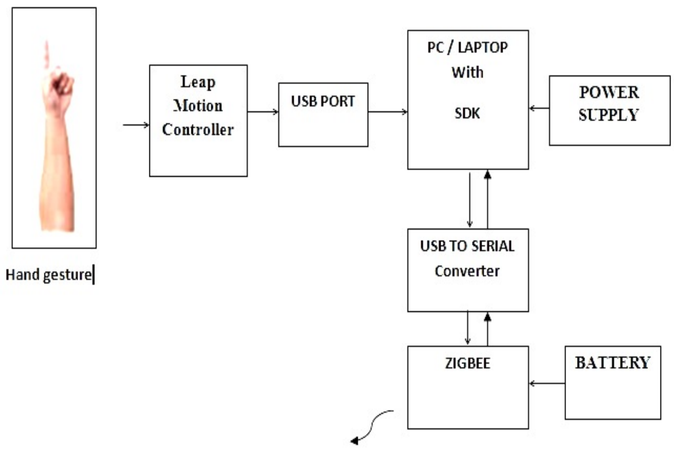

Fig. 4. Hand Tracking Using Leap Motion Controller

Fig. 4 shows the connection of Leap Motion Controller connected via USB communication port and the wireless device (ZigBee) connected via USB communication port with the help of RS232 to USB converter cable which transfers hand gesture information. It operates with a speed of 9600 baud rate.

B. Image acquired by the LMC

Leap motion controller acquires image by camera in the structure of inverted pyramid shape [14]. The frame rate of leap motion controller is 120 frames per second. It has a field view of 135º.

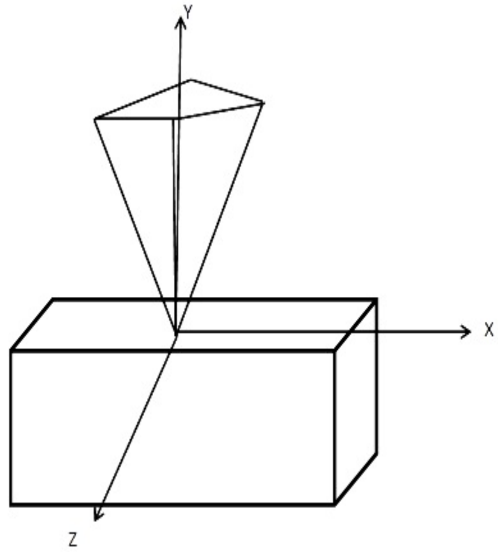

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Fig. 5. LMC and Coordinates

Fig. 5 Leap motion controller gets images in inverted pyramid shape and its coordinate value of LMC consist of LMC_X, LMC_Y, and LMC_Z in equation is denoted by R.

$$R = \begin{bmatrix} LMC\_X \\ LMC\_Y \\ LMC\_Z \end{bmatrix} \quad (1)$$

$$R' = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} LMC\_X \\ LMC\_Y \\ LMC\_Z \end{bmatrix} + \begin{bmatrix} dx \\ dy \\ dz \end{bmatrix} \quad (2)$$

$$R' = \begin{bmatrix} LMC\_X + dx \\ -LMC\_Z + dy \\ LMC\_Y + dz \end{bmatrix} \quad (3)$$

Where dx, dy, and dz are the constants of the distance between origin of the coordinate system of LMC.

C. Convert Virtual Hand Gesture Data into Robotic Hand

Virtual hand information is received from remote computer by ZigBee transceiver interfaced with pic16f877a microcontroller through UART communication with the speed of 9600 baud rate. It has the same speed as transmitter ZigBee connected in computer for real hand tracking.

Fig. 6 shows Robotic Arm connected with pic16f877a microcontroller. The robotic arm receives the commands from real hand via ZigBee wireless communication. This robotic arm uses SG 90 servo motor to control fingers of robotic arm. Each finger in robotic arm has separate SG 90 servo motor our five fingered structure has five SG 90 servo motors.

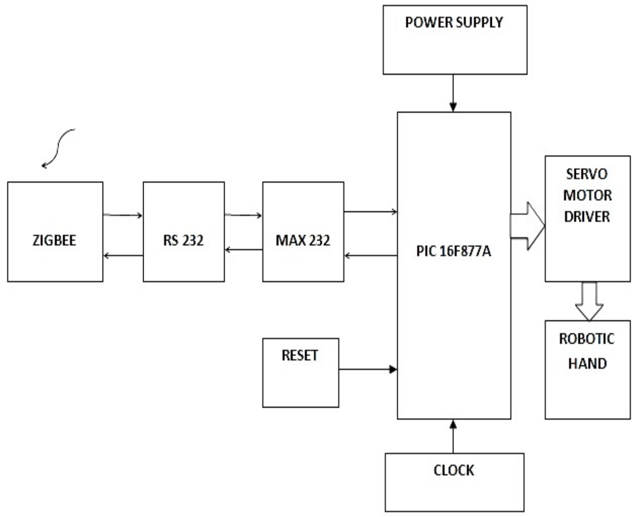


Fig. 6. Robotic Arm Control by LMC

D. Artificial Neural Network

Hand gesture recognition is carried on by classifying the hand gesture data. To enhance the recognition process, the Artificial Neural Network (ANN) is introduced. The ANN model is developed based on biological neural networks that constituent of the human brain structure. Numerous neurons connected and form a network thereby passing the data. It is also called nodes. ANN consists of three layers such as the input layer, the hidden layer, and the output layer which is depicted in Fig 7. It set the input data onto a set of expected output data where it process and passes the data to hidden layers.

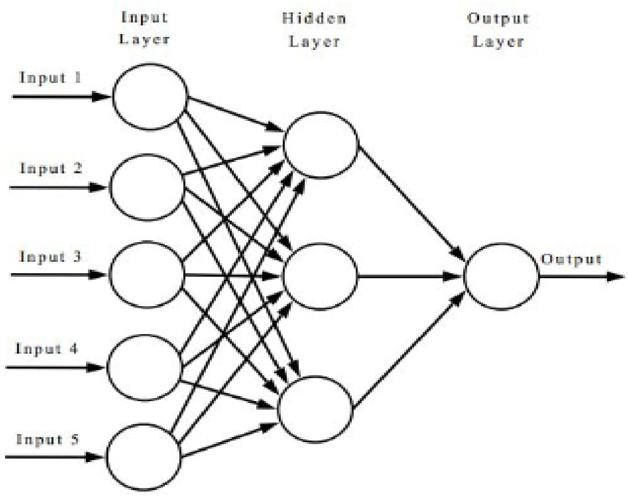


Fig. 7. Diagrammatic representation of ANN

The neurons are connected by a link that stores the information about the input signal. Those connection links associated with a weight. The output signals are generated by the combination of the input signal and activation function. Then the signal gets a transfer to the other unit. The hand gesture signal is processed in ANN where signals are passed among the neurons. Each layer optimizes the signal to extract the vital features from it. The output layer generates the gesture code.

The ANN provides vast benefits in processing the data such as parallel processing capability, storing valuable information, the capability to work with incomplete knowledge, numerous memory distribution, and fault tolerance. Fig. 7 shows ANN layered architecture.

IV. HAND GESTURE CODED DATA

The Table I shows gesture image information analyzed by the Leap Motion SDK. Gesture image information is coded as text for wireless communication to transfer data to the robotic Arm.

Table I
Hand gesture code

Hand Gesture	Gesture Name	Coded Data
	Swipe	A
	Grab	B
	Pinch	C
	Close	D
	Release	E

Hand gesture recognized by the leap motion controller is coded in Table I. This text code is sent through Zigbee wireless communication.

V. ROBOTIC HAND DESIGN

This robotic hand has palm and five fingers such as human and it is interfaced with servo motor to control. In this the structure of hand is nearly the same as human hand.

Fig. 8 shows the internal view of robotic hand with five servo motors to control the five fingers. Each finger has separate control by servo motor [4].

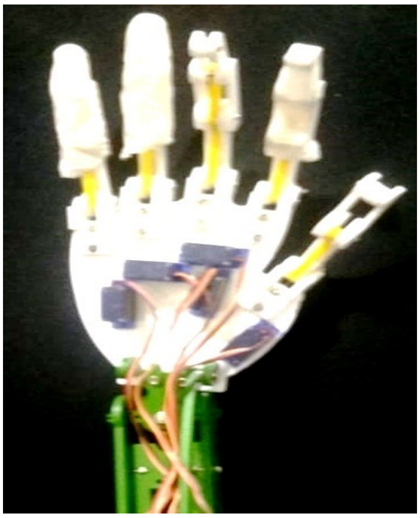
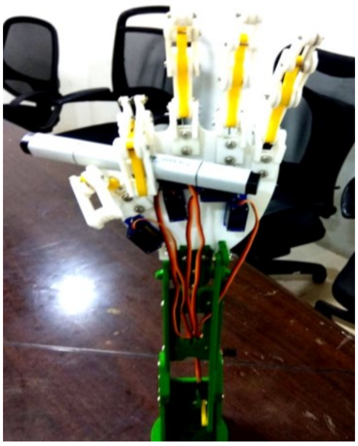


Fig. 8. Robotic hand internal view

VI. RESULT ANALYSIS

Robotic hand mimics similar to the hand of human controlled from remote area. Fig. 8 shows comparison of human hand, virtual hand and robotic hand.

(a) Real Hand (b) Virtual Hand



(c) Robotic Hand

Fig. 9. Comparison of hand gesture (a).human hand , (b)Virtual hand and (c) Robotic hand

Fig. 9(a) shows human hand in front of leap motion controller, Fig. 9(b) shows virtual hand in PC/ Laptop and the Fig. 9(c) shows robotic hand performs as per human activities. Fig. 10 shows different gesture result of robotic hand.

The hand gesture method recognized by leap motion controller which transfers the same information to virtual environment of PC/Laptop while same information is transferred to robotic hand through wireless communication [15].

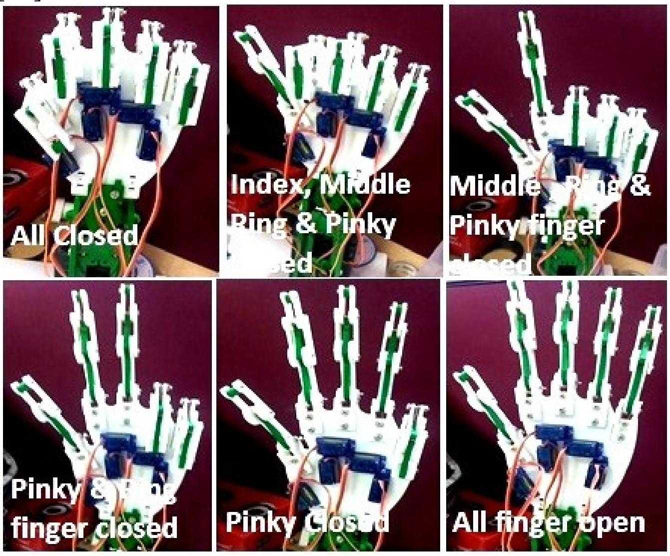


Fig. 10. Gesture Result

Table II. Gives the accuracy of experimental prototype tested under various hand gestures from 4 different people with performance of Swipe, Grab, Pinch, Close, and Release gesture of the hand. Fig. 11. Shows the bar chart of the accuracy obtained under different test conditions.

Table II
Gesture Test

Gesture	Test	Accuracy
Swipe	4 Times	80%
Grab	4 Times	98%
Pinch	4 Times	65%
Close	4 Times	98%
Release	4 Times	98%

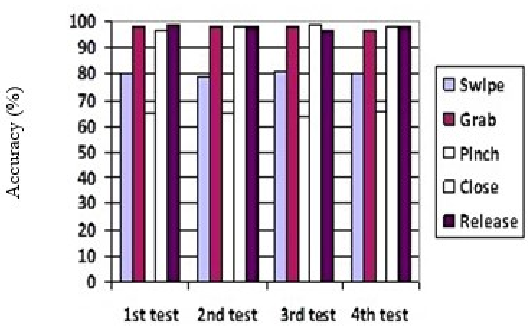


Fig. 11. Gesture Test under different People

VII. CONCLUSION

In this research work, hand gesture and its interaction are used to control robotic arm. LMC observes hand and finger gestures. It displays a three dimensional image of hand and mimics robotic hand like human hand activities. The proposed concept of linked virtual environment with real time environment is found to perform better.

This robotic hand can perform operations in space research center, satellite, drone control, and places beyond human reach.

In future, latency of leap motion controller can be reduced by the new version of SDK. Speed of wireless communication might be improved by the new types of wireless communication. The proposed concept can be implemented in remote operated robotic application.

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